EARLY AIR FORCE FLIGHT TEST CENTER (AFFTC) EXPERIENCE WITH PERIPHERAL VISION HORIZON DISPLAYS (PVHD)

B. Lyle Schofield
Air Force Flight Test Center
Edwards AFB, California

Three separate AFFTC tests were conducted in 1980 and 1981 on two models of the PVHD (Malcolm Horizon). A fixed base simulator test was conducted with twenty test pilot subjects using the Flight Simulator Demonstration Model which incorporated a Helium Neon laser as the light bar medium. Two separate flight tests were conducted by the Test Pilot School classes 80A and 80B in a Twin Otter commuter aircraft using the Stage A Model PVHD. The Xenon lighted A Model was tested in its original configuration which incorporated an AFFTC designed and manufactured hood. With the hood it projected a thinner, distinct light bar. All of these tests are reported in detail in the reference. Only a few general remarks concerning the tests and unrestricted, overall conclusions reached by the author will be presented here.

The test conducted in the fixed base simulator was a pre-prototype of the present Garrett Model B Malcolm Horizon. All of the computations for combining the pitch and roll signals were done in the simulator system and were then transmitted to the projector for projection onto the instrument panel. Ground loop problems and inertial effects on the projector x-y mirrors resulted in a display which had some flicker and waviness and often broke up into two lines slightly separated on the sweep and return. Despite these problems, the display was reasonably sharp and distinct.

The simulated aircraft was a modern fighter with overall handling qualities of Level 2 (desired performance requires moderate pilot compensation). The intent was to provide the pilot with an aircraft that was moderately unstable and would require pilot attention to maintain attitude control and thus be able to evaluate the utility of the PVHD in assisting the pilot to control the aircraft.

Because of the limited availability of the evaluation pilots for extended training with the new display concept, and because of the short evaluation time available, it was decided that the evaluation would be qualitative only. A questionnaire was developed which covered the areas of horizon line characteristics, assistance of the PVHD in performing the evaluation maneuvers, pitch scale sensitivity and a judgment of the applicability of the PVHD concept to flight. The questionnaire was reviewed by the pilot prior to the evaluation and was then filled out by him immediately following the evaluation.

The evaluation task was developed around a ground control approach (GCA) task which included a holding pattern. The timed turns, descents, and speed changes were provided to the pilot on a pilot card and knee board. The evaluation pilot had to refer to the knee board to keep track of both the maneuver sequence and timing. This resulted in some distraction from the instrument panel. Additionally, at random times during the GCA maneuvers, the pilot was asked to copy flight clearance information. This also caused distraction from the instrument panel. Other tasks of switch selection on side console panels were added to provide distraction from the instrument panel.

The evaluation task was performed first with the PVHD on and then was repeated with just the conventional instruments. This order was to reduce any bias for the PVHD. The display was also used at ambient light settings of 2.1- and 15.1-foot candles to evaluate lighting contrasts for the 0.9 milliwatt laser beam.

The results of the evaluation did not show that the PVHD was compelling in terms of providing a replacement for the natural horizon. The laser light bar was determined to be generally adequate in providing help in recognizing and controlling aircraft attitude, particularly when the pilot was distracted from the instrument panel by tasks other than aircraft flight path control such as copying flight clearances. This result was not unanimous but 40-50 percent of the pilots indicated an improvement with the PVHD on and the rest of the pilots said it was the same with or without the PVHD. Sixty percent of the pilots responded that the PVHD would be applicable to flight.

Inflight evaluations of the A Model PVHD were conducted by two successive Air Force Test Pilot School classes (classes 80A and 80B) as class projects. Class 80A evaluated the A Model in its original configuration. The light bar for the original configuration was about three inches wide, was fuzzy, and extended over most of the evaluation pilot's panel. The roll axis of the light bar, although not marked, was directly in front of the pilot. All of the evaluations were conducted in simulated instrument meteorological conditions (IMC). This was accomplished by placing amber colored plexiglass panels over all of the cockpit windshields and then having the evaluation pilot use a matching blue visor which completely blocked external vision. The unhooded safety pilot had unrestricted external visibility. This was an excellent simulation of IMC except for some small shafts of light which got around a few edges of the windshield amber plexiglass and poor instrument panel lighting for the blue-visored evaluation pilot. The problems of the wide unmodified A Model light bar and poor visibility of the instrument panel for the evaluation pilot made the results of this evaluation suspect. Consequently, they will not be reported here. (Refer to the reference for full details.)

As previously stated, the hooded A Model Malcolm Horizon provided a much thinner (less than one inch width), distinct light bar. Also, a small section of the light bar was blanked out to indicate the roll axis. This modified display was used by class 80B. Other changes made by Class 80B were to exchange the evaluation pilot's visor with blue ski goggles, provide better instrument panel lighting, and block out the small shafts of external light with electrical tape. The whole evaluation setup was much improved over those for Class 80A. Most of the changes were recommended by Class 80A based on their experience.

The evaluation tasks used by Class 80B were timed "vertical S" maneuvers. The following conditions were maintained for the four climbs and descents which constituted a vertical S set. The required accuracies are in parenthesis.

Airspeed — 100 KIAS (±5 knots)
Altitude — 6000 feet MSL ±40 feet (±25 feet)
Time for one climb or descent — 30 sec (±5 sec)
Bank angle — 0 deg and 30 deg (±2.5 deg)

The required accuracies had to be maintained during a vertical S set for satisfactory performance. Vertical S maneuvers were flown both with and without the PVHD on.

Four sets of vertical S maneuvers were conducted, each set increasing in difficulty. The four sets were as follows:

A — 0 deg Bank Angle
B — 30 deg Bank Angle
C — 30 deg bank reversal at the top of each vertical S
D — 30 deg bank reversal at the top and bottom of each vertical S

A workload task was devised based on lights at each top corner of the evaluation pilot's front windshield, well out of the pilot's normal field of view. These lights were randomly lighted throughout the vertical S maneuvers and then as soon as he recognized they had been lighted he turned the light off with a button on his control column. The time required to recognize that a light had been turned on and then to turn it off with the button on the control column was measured and evaluated as a measure of pilot workload.

The six non-project evaluation pilots were given one sortie which constituted a series of A through D vertical S maneuvers with the PVHD on and then a repeat of the same maneuvers with the PVHD off. The two project pilots had five sorties each so they were higher on the learning curve.

The results of the measured workload showed that the project pilots did slightly better with the PVHD on and the non-project pilots slightly better with the PVHD off. However, the improvements for both the project and non-project pilots could not be considered significant.

The performance results (maintaining maneuver accuracy) showed a moderate improvement by the project pilots with the PVHD on and no difference for the non-project pilots with the PVHD off. Again the differences were not considered to be significant.

All of the pilots were asked to make a subjective pilot rating of the utility of the PVHD. The non-project pilots rated the PVHD on and off as providing no difference. The project pilot's ratings were weighed in favor of the PVHD on, but again the results could not be considered to be significant.

The conclusions of all three AFFTC evaluations of the PVHD concept were that it has not yet been adequately evaluated. There seems to be a significant learning curve associated with the PVHD and the project pilots because Test Pilot School Class 80B only got a good start on the learning curve. After all, a lengthy learning curve should be anticipated in view of the training period required for the attitude display indicator (ADI). This does seem to point out that the PVHD is simply not as compelling as the natural horizon in its present form. It can also be concluded that any attempt at a valid evaluation of the PVHD concept can be done only under IMC or validly simulated IMC conditions. The knee in the learning curve, however, may be reached without full IMC although it may take much longer to reach.

REFERENCE

Schofield, B. L.; Coombs, D. F., Capt USAF; Tudor, D. I., Capt CAF; et al. Interim Report of Air Standardization Coordinating Committee, Test Project Agreement 769-10 (CF/USAF) Peripheral Vision Horizon Display (PVHD) Stage A Model, D STDZN C3, National Defence Headquarters, Ottawa, Ontario K1A OK2, Canada.